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Dr. James Balsiger
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P.O. Box 21668
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April 13, 2004

RE: Comments on Alaska Region Essential Fish Habitat Draft Environmental Impact Statement

Dear Dr. Balsiger,

Since we last spoke, I left my position at Oceana last July 2003 to pursue a Ph.D. in Stanford University's Interdisciplinary Program in Environment and Resources. In the course of my studies, I have conducted extensive review of the Alaska Region Essential Fish Habitat Environmental Impact Statement (EFH DEIS). As you know my interest in this document comes not only from the 18 months I spent working on this issue, but also from my love for Alaska's incredible ocean habitats and desire to see a profitable, sustainable groundfish fishery continue in Alaska. My current fields of study in Fisheries Economics and Marine Ecology at Stanford have broadened my understanding of the complex issues you face in this decision document and I have used some of the scientific and economic tools I have learned here at Stanford so far to develop some detailed scientific comments I hope you find useful. While I have several fundamental disagreements with the methods and conclusions contained in the EFH DEIS, I hope you view my comments as constructive towards developing an FEIS of highest quality. Furthermore, the tremendous effort and hard work you and your analysts have put into the EFH DEIS is very evident throughout the document and I would like to commend you for this accomplishment.

Comments on Determination of Long-term Effect Index Values in Appendix B

1. The LEI values presented in the Effects of Fishing model indicate loss of each habitat feature if fishing effort in the model occurred for $t = \infty$ (infinity). However, the stock sizes used to evaluate the extent of habitat impacts are from present values. Therefore, if present values are to be used, the loss of habitat features must reflect the same time duration as used in the model. For example, for the case of long-lived corals and sponges, current bycatch rates suggest that equilibrium levels of habitat loss have not yet been reached. This is because there is no evidence of recovery thus far in areas of corals and sponges that have been damaged. Therefore, in addition to the equilibrium levels of habitat loss shown by the LEI values in the EFH DEIS, the dynamic model contained in Equation 4 (page B-5) should be used based on the best available information on fishing effort that has occurred to date. Showing the results of Equation (4):

$$H_t = H_0 (I e^{-(1+\rho S)t} + \rho S) / (I + \rho S), \text{ where } S = e^{-I}$$

in addition to the results of Equations 5 and 6 (the LEI values already shown in the EFH DEIS) will allow the public and decision-makers to evaluate how close to equilibrium the current habitat losses are, and how much additional habitat loss will occur if status quo fishing is continued. Since it is a dynamic model, the EFH EIS should include the trajectory of habitat loss through time. This dynamic model should also be used to show how each mitigation alternative will change the trajectory of future losses of each habitat feature.

Fishing effort data used in the effects of fishing model was from a five year dataset from 1998-2002 (page B-10). Using this dataset to develop the long-term effects index assumes that all past and future fishing effort has been and will be identical to the effort that occurred in this five-year period; therefore, if bottom trawl effort distribution changes in the future, LEI values as calculated in the EFH DEIS will be inaccurate. In fact, the LEI values in the EFH DEIS will be systematically underestimated, particularly if fishing effort occurs in new areas with low recovery rate habitat features. For example the EFH DEIS states:

“Because the very slow recovery rate of these organisms results in very high (more than 75 percent LEI) eventual effects with more than the most minimal amount of trawl fishing (annual trawl effort less than one tenth the area of the block), the distribution of high LEI values directly reflect the distribution of blocks subject to more than minimal trawl effort” (page B-21)

The only way to ensure that bottom trawl effort does not move to new blocks is through an open area approach (as described in Alternative 5B), where future trawl effort is only allowed in areas where “more than the most minimal amount of trawl fishing” occurred in from 1998-2002. If such an approach is not taken, the EFH DEIS must show evidence that other measures will act to prevent trawling in new areas. Otherwise, LEI values based on those five years of trawl effort data are systematically inaccurate and underestimated, particularly for corals and sponges.

2. Known information on growth rates of sponges from the literature was not used in determining the recovery rates of living structure. In particular, Leys and Lauzon (1998) found the average growth rate of sponges found in British Columbia to be 1.98 cm per year. This study found that the age of an average-sized sponge to be 35 years, and large individuals (1 m in length) were estimated to be 220 years old. These same sponge species are found throughout the Bering Sea, Aleutian Islands, and Gulf of Alaska. Since sponges are in the “Living Substrates” habitat category, the “Rho” values used in this category should reflect these high recovery rates. For example, the “Rho” value based on a 220 year recovery rate would be 0.0045, which is substantially lower than the Low, Central, and High Effect Estimate % as shown for hard substrate Living Shelter habitats as shown in Table B.2-6. Furthermore, since age does not include recolonization time between impact and settlement of new biogenic structures, all recovery times used in the EFH EIS that were derived from literature on ages are systematically underestimated.
3. In calculating aggregate LEI values over each of the three major regions (Aleutian Islands, Gulf of Alaska, and Bering Sea), the distribution of coral and sponge habitat features was assumed to be uniform. While this does not affect the LEI values in each 5 x 5 km block, it affects the aggregate LEI score.

Summing of LEIs without feature distributions assumes that all locations in each habitat have equal value. Actual combined effects would be more affected by areas of high abundances than low. Therefore, accumulated LEIs will underestimate real effects a feature that was originally more abundant in heavily fished areas than in those that were fished lightly or not fished (Page B-6).

While the EFH DEIS states in several places that the data is sparse regarding coral and sponge distribution, there are two data sources that can be used to correct this assumption. The first is trawl survey data, which contains CPUE data for corals and sponges throughout trawlable habitats in all three Alaska regions (AI, GOA, BS). Heifetz (2002) and Malecha et al. (2002) conducted analysis on the distribution of benthic structure-forming invertebrates directly from this dataset. Although some areas were not sampled, this best available information could be used to extrapolate relative abundances of habitat features to the unsampled areas. Observer bycatch data can be used to calculate CPUE data of corals and sponges as well as bycatch rates of these habitat features per metric ton of total catch; therefore, this information can be used to develop relative abundance estimates for corals, sponges, and other biogenic habitat types between different blocks.

Though CPUE may not be appropriate to calculate total abundance of these habitat types (due to the fact that trawl gear may not retain all corals and sponges in the trawl path), it can be used to calculate relative abundances of these habitat features between blocks. The fact that there are different relative abundances of these habitat features contradicts the assumption made in the EFH DEIS. This relative abundance information should be used to weight each block-specific LEI value as input into the calculation of an aggregate LEI value for each habitat feature by region.

4. The EIS attempts in several places to discount the high LEI values for coral given by the Effects of Fishing model in the Aleutian Islands and Gulf of Alaska. Appendix B mentions potential biases for coral LEIs based on the “patchiness” of coral habitats and fishing effort within each block (Page B-22). The EIS states that

“In hard-bottom areas, fishing location must consider both seeking higher abundances of fish and avoiding structures (including rocks, rough bottom, and coral) that may damage fishing gear. This tends to move fishing effort toward smoother seafloors and away from some coral habitats.” (Page B-22 and B-23).

The EFH DEIS does not cite any evidence for this assertion and therefore it should be removed from the document unless there is literature to show that this bias actually exists. In particular, there is no evidence showing that coral or sponge bycatch damages bottom trawl gear. There is evidence contradicting a bias away from some coral habitats. For example, the EFH DEIS states that:

“High overlap of habitat-use and fishing would produce underestimates of habitat effects, while separation between patterns would produce overestimates. Underestimates would be most likely for features used by adult fish that are targeted by the fisheries” (Page B-11)

Therefore, if there are higher densities of adult fish in coral and sponge habitats than in other habitats, this statement suggests that LEI values for this habitat feature are underestimates due to the resulting higher fishing in these habitats within each block. This higher density of

adult FMP fish is confirmed by preliminary analysis by R. Stone showing that 87% of adult FMP fish in the Aleutian Islands transects were found in association with biogenic habitats, while 13% were associated with other habitat types. Further evidence for fish associations with corals and other living substrates are documented in Heifetz (2002), Malecha et al. (2002), and Krieger and Wing (2002).

In addition, the Pacific Ocean Perch (POP) fishery is widely known to target areas with complex habitat to increase their “bycatch” of more valuable rockfish species even though the entire POP TAC could be attained in the off-bottom mode due to the diel semi-pelagic behavior of POP.

5. The LEI maps for coral contain a note: “LEIs were calculated wherever fishing occurred. The distribution of coral is much more restricted, but not specifically known. Therefore these charts indicate reductions in many areas where no coral, and hence no actual coral loss, occur” (Figs B.2-6 a,b,c). However, comparing the locations of high LEI values on the map correlate very closely with the areas where actual coral bycatch was observed in the Aleutian Islands (see Maps below, top provided by Oceana based on NORPAC observer data).

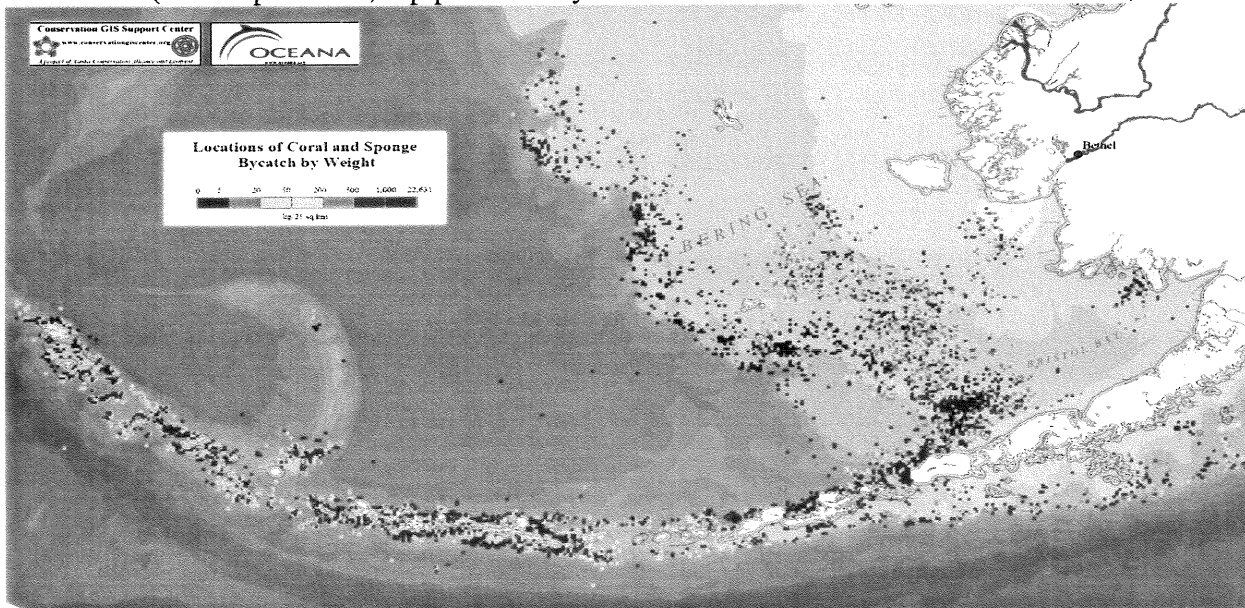
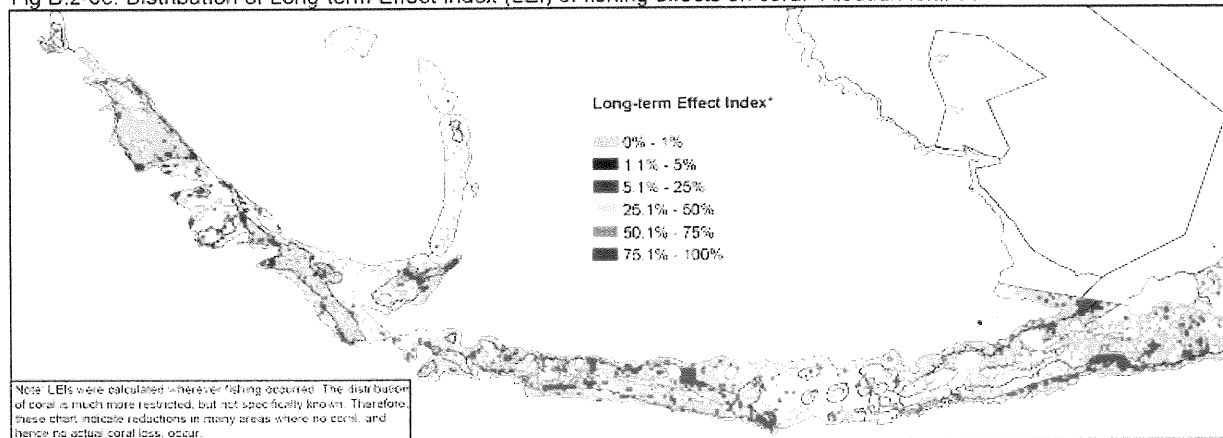
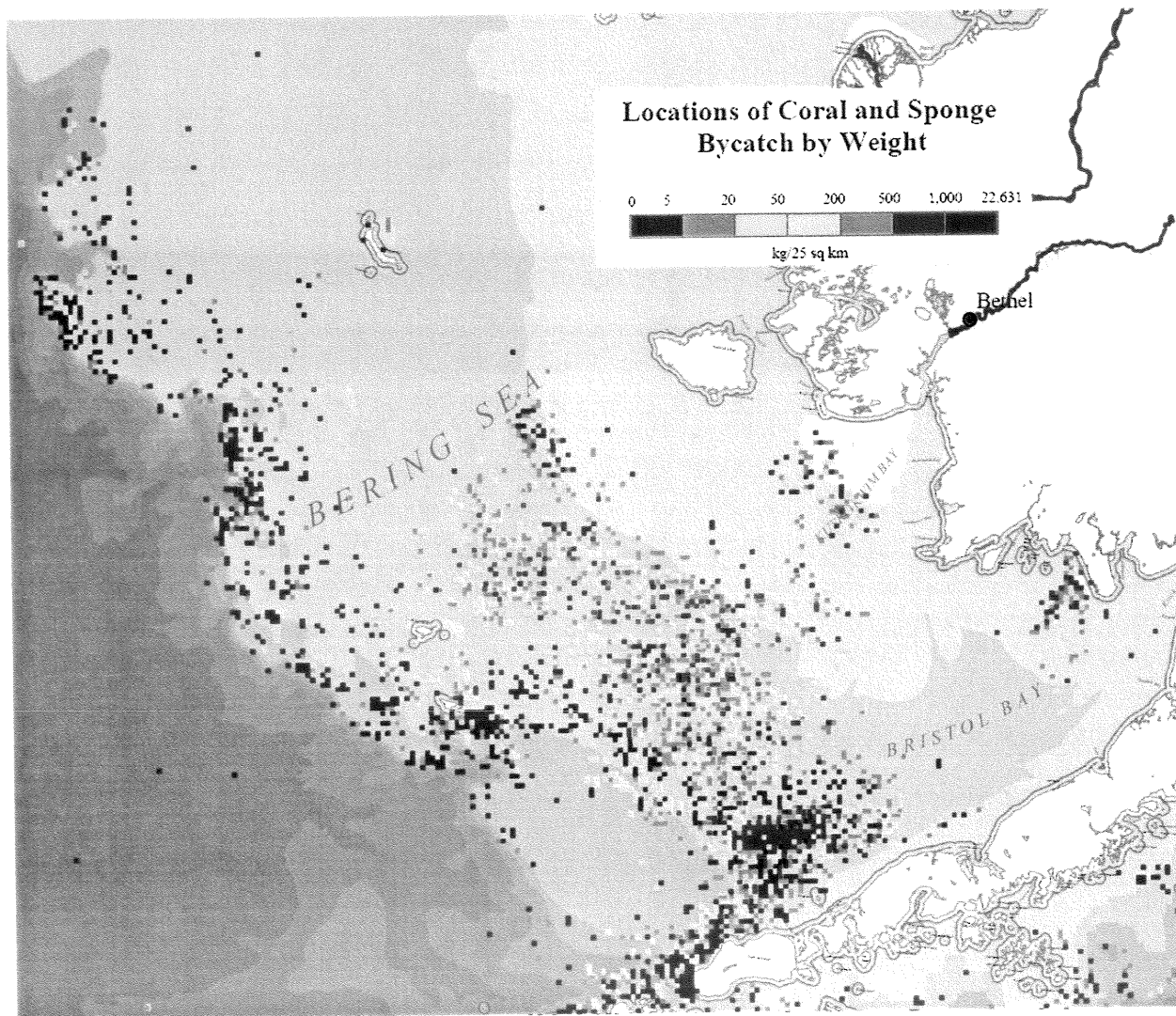


Fig B.2-6c. Distribution of Long-term Effect Index (LEI) of fishing effects on coral- Aleutian Islands



6. The EFH DEIS did not consider impacts to corals or living substrates in the Bering Sea with recovery times greater than 10 years (Table B.2-6 and Table B.2-8). However, coldwater sponges, which have been shown to live 220 years (Leys and Lauzon 1998), are abundant in the Bering Sea and this region also contains many species of deep sea corals whose ages and recovery rates are not known. In the absence of age data for these species, a precautionary approach would be to assume recovery rates (“Rho”) values are similar to other similar corals and sponges. The conspicuous absence of LEI values for coral (Fig B.2-6a and Table B.2-8) seems to contradict the trawl survey data on abundance of these species as well as observer data. For example, observer data you site in a letter addressed to Jim Ayers, Pacific Director for Oceana, on October 17, 2002, shows that 150,861 kg of corals and bryozoans and 1,208,225 kg of sponges (total of 1,359,086 kg) were reported as bycatch from bottom trawl fisheries in the Bering Sea from 1990-2002 from sampled catch only. Sampled catch for Bering Sea bottom trawl fisheries over this period accounted for 72% of the Official Total Catch, based on data cited in the same referenced letter. Spatially, the spatial distribution of this bycatch is depicted in the following map:



From map produced by Oceana and Conservation GIS Center, based on NORPAC Federal Observer database aggregated by 5 x 5 km block from 1990-2002.

This data provides scientific justification from the best available science that the Effects of Fishing on corals and sponges in the Bering Sea should be included in the LEI values.

Again, notice from this map that the areas of highest bycatch (dark red) do not match the areas of highest LEI score (yellow, orange, red) for Living Substrate in the Bering Sea (Fig. 2-4a). This highlights the failure of the LEI maps to show areas where the impacts to specific habitat features are greatest, which is due to model's assumption that these habitats features are uniformly distributed. This shows why observer data and trawl survey data should be used in the LEI model to give different initial abundances of these habitat features to each block in determining aggregate LEI values.

Determination of Minimal and Temporary Adverse Impacts of Fishing on EFH

Stock size is an inappropriate measure of whether adverse fishing impacts to EFH are minimal. Direct quantitative and/or qualitative measures of habitat loss should be used instead.

The EFH DEIS states:

Essential habitat is that necessary for the managed species to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. For purposes of this assessment, the ability to support a sustainable fishery is to be judged on the stock's ability to remain above the Minimum Stock Size Threshold (MSST). (Appendix B, Table B.3-2)

Appendix B Page B-24 states that "Literature and other sources of knowledge regarding what each species requires to accomplish spawning, breeding, feeding and growth to maturity" were used to determine whether the adverse effects of fishing on EFH are more than minimal and not temporary. However, several literature sources regarding the use of corals and sponges in spawning, breeding, feeding, and growth to maturity were either absent from the EFH DEIS or were not considered in this part of the analysis. In Alaska, the following species are known to associate with corals and sponges: rougheye rockfish, redbanded rockfish, shortraker rockfish, sharpchin rockfish, Pacific Ocean perch, dusky rockfish, yelloweye rockfish, northern rockfish, shortspine thornyhead, several species of flatfish, Atka mackerel, golden king crab, shrimp, Pacific cod, walleye pollock, greenling, Greenland turbot, sablefish, and various non-commercial marine species (Freese 2000; Krieger and Wing 2002; Heifetz 1999; Else et al. 2002; Heifetz 2002). Deep sea corals are known to provide protection from predators, shelter, feeding areas, spawning habitat, and breeding areas (Krieger and Wing 2002). For example, the only observed instance of golden king crab spawning occurred under a large colony of *Primnoa* (Krieger and Wing 2002). These "Connections" are not included in Table B-3.1 of the EFH DEIS and if included, would result in different conclusions about whether the impacts listed in Table B-3.3 are minimal.

Furthermore, the EFH DEIS states:

The magnitude and distribution of feature LEIs can thus be compared with the distribution of the use of that feature by fish species to assess whether the effects are “more than minimal” relative to that species’ EFH (Section B.3). Effects meeting this second element would necessarily meet both elements (more than minimal and not temporary) due to the nature of the LEI estimates. (Page B-22)

Again, the conclusions reached by the agency through this methodology are flawed due to the omission of scientific evidence for “Connections” between FMP fish and coral and sponge habitats. Since corals and already have been designated as EFH in Alaska, there are major significant losses of this EFH relative to the distribution of commercial species.

Without information on how the productivity of fish is affected by EFH (EFH Level 4), productivity is an inappropriate measure to evaluate the effects of fishing as minimal and/or temporary. However, if productivity is to be used as the indicator, NMFS should use the best scientific information about the relationship between habitat features and fish productivity to determine the effects. The use of stock size in relation to MSST is assumed to be a measure of the productivity. Since no attempt was made to link LEI values to changes in productivity of FMP species, the EIS provides no justification for using stock size as an indicator for habitat impacts.

Stock size in relation to MSST is inappropriate to use to determine whether habitat impacts are minimal for the following reasons:

1. Equilibrium habitat losses as shown with LEI values may have not yet been reached. This is especially likely for long-lived habitat features that continue to have high bycatch rates, such as corals and sponges. Therefore, current productivity or stock sizes do not yet reflect the productivity decreases that will occur once LEI values are approached.
2. There may be a lag time in habitat-mediated changes in fish productivity between when habitat damage occurs and fish productivity declines. This may occur based on demographic features of fish stocks, such as long life spans and/or lag times in the effects of density dependence on mortality. Mangel (2000: p672) states that “...neither catch nor stock is a good indicator of what is happening to the habitat: the decline lags behind habitat destruction and the recovery lags behind habitat restoration. Habitat itself must be monitored.” Mangel (2000) backs this statement through a mathematical model based on modern fishery models used in fishery management.
3. Fish stock sizes are heavily influenced by fishing pressure and other factors besides habitat. For example, Page Appendix B, page B-30 states: “Although both the Pribilof Islands stock and St. Matthew stock of blue king crabs are considered to be below MSST, habitat loss or degradation by fishing activities is not thought to have played any role in the decline of these stocks.” The status of some fish stocks is highly variable and largely influenced by the fishery itself. The current status of a fish stock may be more heavily influenced by environmental factors and/or quota levels, hiding long-term declines in overall reproductive rates or carrying capacities of the fish populations that result from habitat loss.
4. MSST values and BMSY are lower than they would be without habitat impacts. Therefore, since MSST itself decreases linearly with carrying capacity reductions, it is not an appropriate measure. Conversely, if adverse habitat impacts were reversed, MSST would increase (see model below).

Even though the EFH DEIS attempts to relate habitat impacts to fish productivity by considering current stock sizes, the document makes no attempt to identify the functional relationship between habitat features used in the Effects of Fishing Analysis (Appendix B) and the productivity of FMP species. This is likely because many of the habitat associations between corals and sponges and commercial fish were ignored in the analysis as shown above. Page B-24 states that, “The results of the effects of fishing analysis (Section B.2)” were used to determine whether the adverse effects of fishing on EFH are more than minimal and not temporary.” However, the EFH DEIS does not contain any qualitative or quantitative model linking LEI values to changes in productivity of commercial fish. Therefore, the mathematical model used to determine LEI values was not used to determine effects of productivity on habitat, despite the fact that such models exist. For example, Swallow (1990) presented a model for assessing the impacts of a renewable resource, fish, as a result of reductions in a non-renewable resource, habitat. Due to the long recovery times of corals and sponges, this model is appropriate and applicable to answer the question about fisheries productivity. Mangel (2000) developed a model based on Beverton-Holt and Ricker-like recruitment functions showing that loss of spawning habitat is equivalent to additional fishing mortality of the adult stock; or in other words, productivity loss.

Another way to answer the question about degree of adverse impacts is to directly measure the degree to which habitat characteristics are reduced. For example, since corals and sponges have already been designated as EFH, the question should be how much corals and sponges has been damaged (quality) or removed (quantity) and are these quantities minimal and temporary? This data is available for the major habitat-forming species from bycatch records, including corals, sponges, tunicates, anemones, and sea whips. The Draft EFH EIS made no attempt to do this. Observer data is the most accurate data set for monitoring the catch and bycatch of Alaska’s commercial fisheries and is used regularly in enforcement and development of fisheries regulations. From a scientific perspective, it is unclear why such a direct data source was ignored in the determination of whether adverse effects to EFH are minimal and temporary.

Consideration of minimal impacts rests in the scale of reference. In Appendix B, many specific 5 x 5 km blocks throughout Alaska’s EEZ have LEI values from 50-100%, particularly for corals and living structure. Localized impacts were observed *in situ* by Zenger (1999), who observed historically trawled coral habitat areas that have been completely destroyed, with only fragments of coral skeletons and rubble remaining. In these specific areas, no reasonable scientist could claim that the adverse impacts were minimal; therefore, it is not clear why NMFS chose to focus only on aggregate LEI values instead of determining whether impacts were minimal and temporary in each block in the analysis. This is particularly noteworthy considering that the EFH Final Rule includes “site-specific or habitat-wide impacts” in its definition of adverse impacts on EFH. (50 CFR 600.810(1))

Use the best available science to show quantitative economic and ecological benefits resulting from each alternative.

The EFH DEIS has provided no adequate quantitative analysis of expected economic benefits of increased fisheries productivity as the result of trawl closures. This makes it impossible to evaluate whether habitat impacts are minimal and temporary or whether mitigation measures are

practicable. White et al. (2000) showed that the costs of a marine reserve for tropical coral protection were greatly outweighed by the benefits from higher catches. Changes in LEI values as well as identification of production functions provide a straightforward methodology to determine economic benefits from increased fish productivity. Estimates of revenue changes associated with each alternative must include the value of increases in productivity of FMP species as a result of changes in habitat impacts (i.e. projected reductions in coral/sponge bycatch, or if these are not available, projected changes in LEI values).

A Quantitative Model of the Effects of Habitat Impacts on Fisheries Productivity through a Carrying Capacity Mechanism

To help NMFS explore the question of how adverse impacts of fishing on EFH affect the productivity of commercial fish, I have developed a quantitative mathematical model for determining the extent to which LEI values presented in Appendix B reduce the productivity of fish, and how these productivity reductions can be used to determine whether the adverse effects of fishing on EFH are minimal. I plan to submit this model for publication in the scientific literature.

Logistic Growth

Although there are many fishery models, most modern models exhibit the basic characteristics of logistic growth and density dependence. I will use a basic equation for logistic growth for purposes of illustrating how habitat impacts can be incorporated into any fishery model to determine reductions in fish productivity:

$$dN / dt = r * N * (1 - N / K) \quad (1)$$

where dN/dt equals the instantaneous rate of increase in the population, r equals the intrinsic rate of increase, N equals the stock size, and K equals the carrying capacity. The intrinsic rate of increase (r) is generally determined by the life history of the fish species, particularly its survivorship and fecundity at each life stage. The carrying capacity (K) represents the limits to growth of the population, generally determined by the available habitat and resources, such as food and shelter. It is assumed that r and K are determined by ecological factors and the biology of the fish species and as mentioned before, not by stock size. The population trajectory for such a population is a sinusoidal curve which at low stock sizes increases exponentially, reaches a maximum growth rate when the population size is half of the carrying capacity, and levels off as N approaches K (see figure 1).

The inclusion of a carrying capacity assumes that there is density dependence, where at high population densities, the competition for resources or habitat within the population limits its growth. In this simple model, the parameters r and K are considered exogenous factors that do not change. The production function including harvest (h) in the calculation is given by:

$$dN / dt = r * N * (1 - N / (K)) - h \quad (1a)$$

Hence, there is no change in the population size when the harvest rate equals the growth rate of the population. When this occurs, a sustainable harvest rate has been attained.

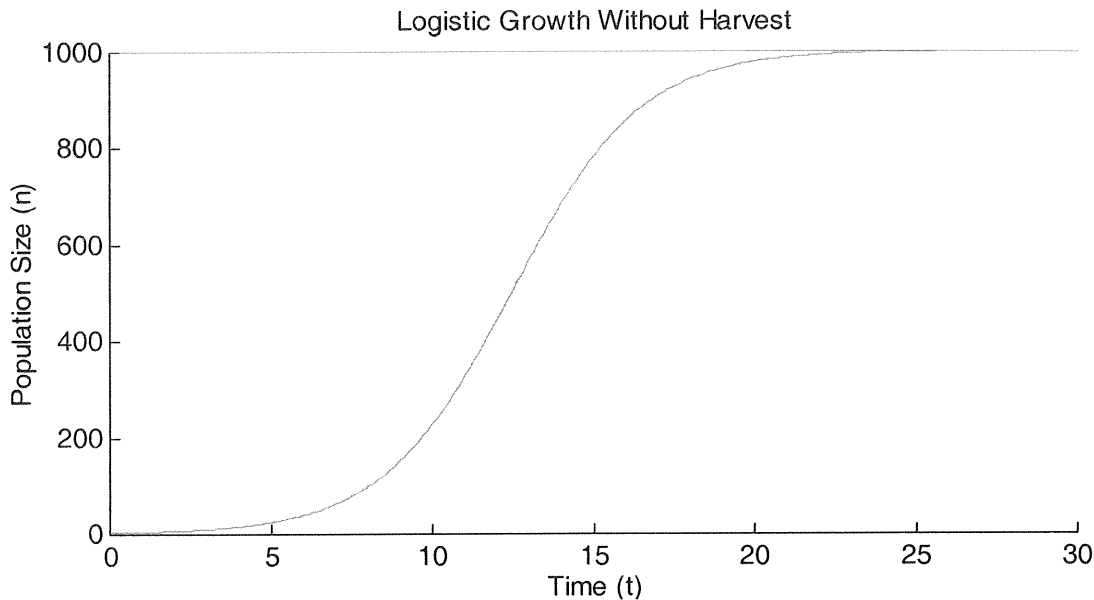


Figure 1: General population trajectory for a population with $r = .5$, $K = 1000$. The population trend (green) increases until it plateaus at the carrying capacity (K) (red). The growth rate of the population is the slope of the line. Maximum growth rate occurs where population is at $n = 500$.

The production function associated with logistic growth shows the instantaneous rate of increase in the population size (dN/dt) for any stock size between 0 and the carrying capacity. The rate of increase can also be thought of as the sustainable harvest level for any stock size, in which a harvest rate on the curve will cause no net change in the stock size. Since the logistic equation is quadratic, the characteristic shape of the production function is an upside-down parabola intersecting the x-axis at population sizes of 0 and the carrying capacity (See Figure 2). There is a characteristic production function for any given combination of r and K . The maximum of the function occurs when the stock size is N_{max} (Equation 2) and the maximum production rate is the maximum sustainable yield (MSY) (Equation 3):

$$N_{max} = K / 2 \quad (2)$$

$$MSY = r * K / 4 \quad (3)$$

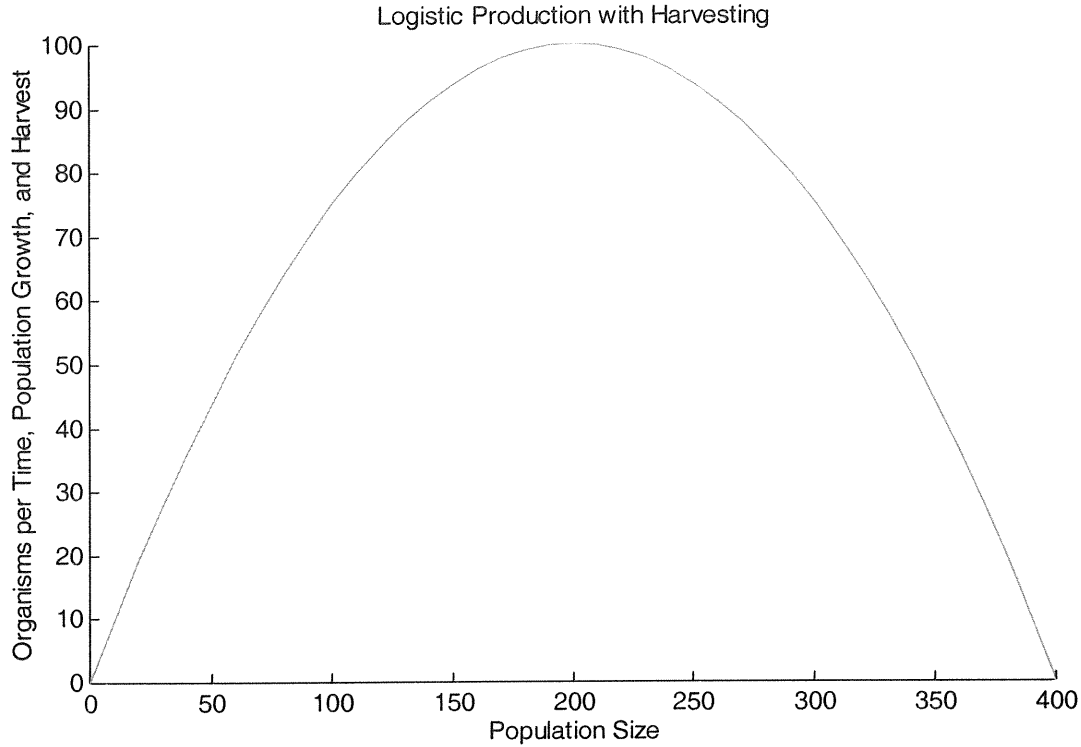


Figure 2: Production Function for a population with logistic growth for $r = 1$, $K = 400$. This curve specifies the rate of population growth or the sustainable yield for any given stock size between 0 and carrying capacity. Maximum Sustainable Yield (MSY) is the point of highest production, occurring at a stock size of 200 with a value of 100. This means that if the population is at 200, a harvest rate of 100 will not change the stock size over time.

There are several important characteristics of the logistic production function. If the harvest rate exceeds the rate of production, the population will decrease and vice versa. Therefore, there are two equilibrium stock sizes for every harvest rate below MSY. The lower stock size is inherently unstable, while the higher of the two stock sizes is stable. Furthermore a decrease in carrying capacity will decrease both the width and height of the curve, though maintaining its general shape. However a decrease in r will maintain the width of the curve, but lower its height. As mentioned in the Introduction, this model takes r and K to be constant exogenous parameters and the effect of harvest is only on the stock size. Current fishery management allowable catch levels are also based on these assumptions.

Fundamental Equation for Habitat Impacts of Fishing

However, if carrying capacity is also affected by harvest, this model is insufficient. To account for the effect of catching fish on fish habitat, we present the Fundamental Equation for Habitat Impacts of Fishing:

$$\frac{dN}{dt} = r * N * (1 - N / (K - \Omega * h)) - h \quad (4)$$

where Ω is the effect that a constant harvest rate of one unit of stock has on the carrying capacity of the population in equilibrium. Notice that harvest rate appears in the growth components of

the equation and has the effect of reducing the carrying capacity by a factor of Ω . Therefore, for any positive constant value of Ω , carrying capacity decreases as harvest rate increases. Also, as the quantity $K - \Omega * h$ approaches zero, N can never be positive.

Equation (4) was analyzed using similar analysis to that described above for the logistic growth equation and production function without habitat impacts. The main conclusion is that for positive values of Ω and h , the shape of the logistic production function decreases in height and width. At very low harvest rates, the production function is relatively unaffected, while at higher harvest rates the production function changes more dramatically. For any positive value of Ω , a harvest rate at the previous level of MSY exceeds the maximum sustainable yield on the new production function (see Figure 3). Therefore, the previous MSY is no longer sustainable. If Ω is greater than 4, the production function completely disappears if harvest is at the level of the old MSY, since this would drive the carrying capacity to zero. The most significant result of this model, therefore, is that for any given fish population, the MSY depends on the fishing methods used in harvest.

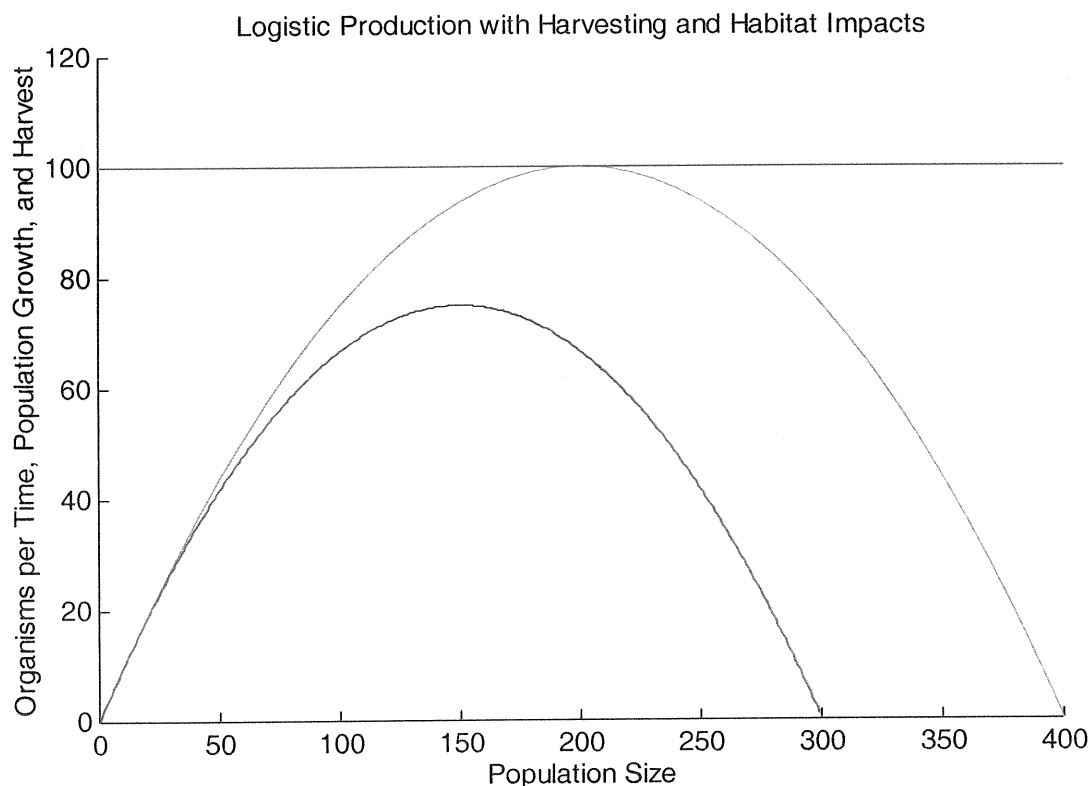


Figure 3: Initial logistic production function without harvesting (green) and logistic production function with harvest rate of 100 (blue) for $r = 1$, $K = 400$, and $\Omega = 1$. Since $\Omega = 1$, a harvest rate of 100 will decrease the carrying capacity (K) by 100, so the new production function has a carrying capacity of 300. Note that this harvest rate of 100 would be equivalent to MSY if there were no habitat impacts. However, with habitat impacts the harvest exceeds all points on the new production function, so this harvest rate is not sustainable at any stock size.

If one begins by looking at the new production function associated with low levels of harvest and gradually increases the level of harvest, it becomes clear that the maximum of the production function falls as harvest increases; therefore, there will be a new MSY where the harvest rate converges with the point of maximum production. This is the actual MSY considering the impacts of fishing on target species habitat. Figures 5a-d show this progression and the MSY for four scenarios with equal values of r and K , but different values of Ω . As shown in the figure, there is a characteristic MSY for every value of r , K , and Ω . The MSY decreases as Ω increases. The equation for MSY with habitat impacts is given by:

$$\text{MSY} = r * K / (r * \Omega + 4) \quad (5)$$

The stock size that is required for MSY to be attained with habitat impacts is given by:

$$N_{\text{max}} = 2 * K / (r * \Omega + 4) \quad (6)$$

Note that these equations are equivalent to Equations (2) and (3) when $\Omega = 0$. From these, we can plot the relationship between Ω and MSY for any given combination of r and K . An example of this relationship is given in Figure 4. As Ω increases, there is an initial steep drop in MSY and the slope flattens with higher values of Ω . Therefore the marginal change in MSY with small changes in destructive gears is much greater for cleaner fishing methods than for more destructive ones. Note that the MSY is half of the 'no habitat impact' MSY when $\Omega = 4$ and is one quarter of the 'no habitat impact' MSY when $\Omega = 12$.

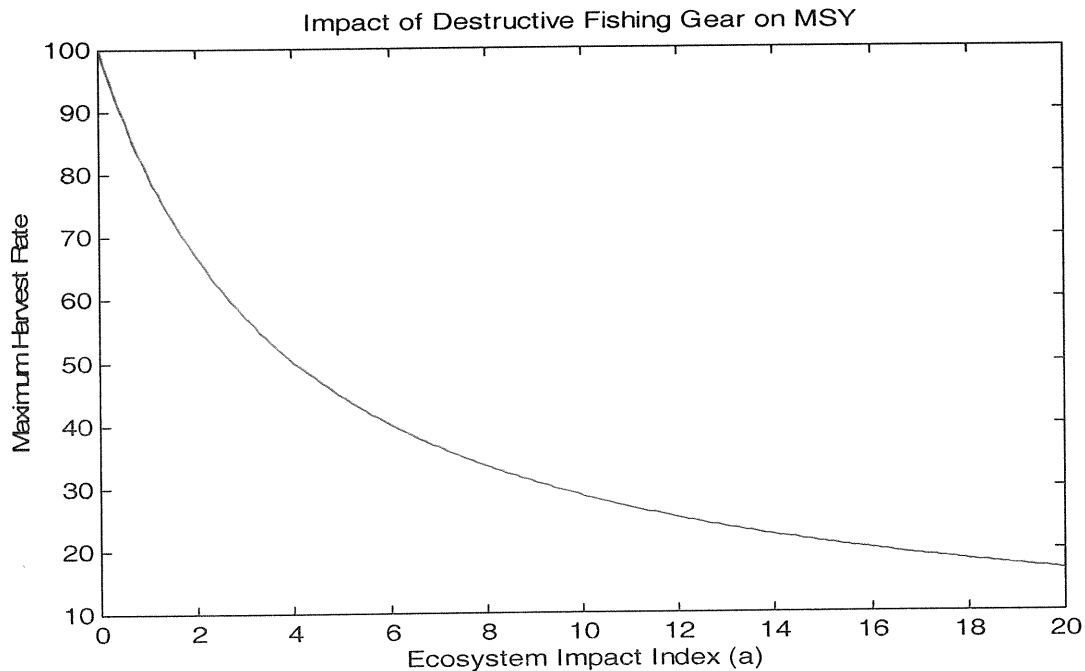


Figure 4: Relationship between ecosystem impact index values (Ω) and Maximum Sustainable Yield (MSY) for a population with $r = 1$ and $K = 400$. Note that at $\Omega = 0$, MSY is equivalent to MSY without habitat impacts.

Figures 5a-d. Adjusted logistic production function at different levels of harvest (h) for $r = 1$, $K = 400$, using $dN/dt = r * N * (1 - N / (K - a * h))$. Growth curves correspond to harvest rates of same color. Harvest at Maximum Sustainable Yield (MSY) represented in blue.

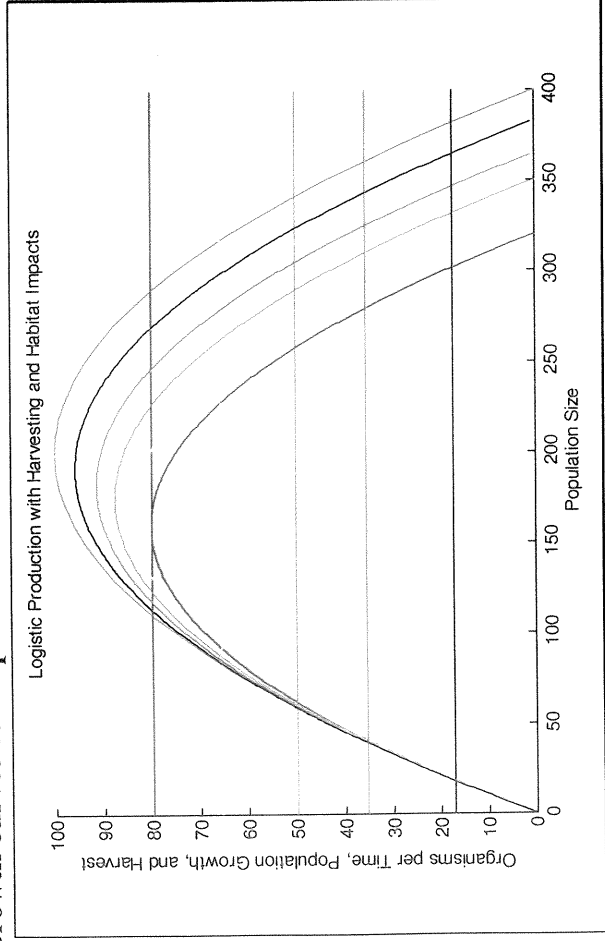


Figure 5a: $\Omega = 1$, MSY = 80.0

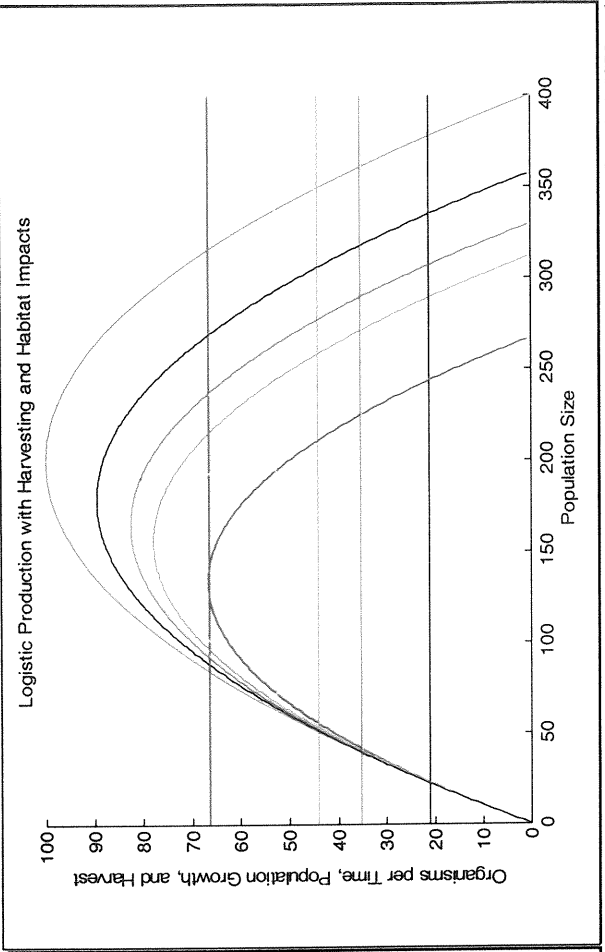


Figure 5b: $\Omega = 2$, MSY = 66.7

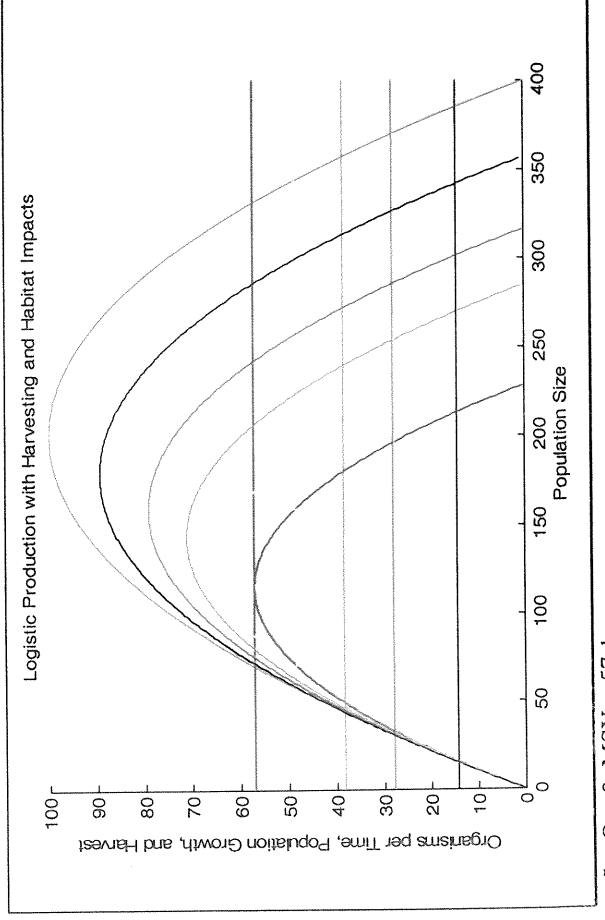


Figure 5c: $\Omega = 3$, MSY = 57.1

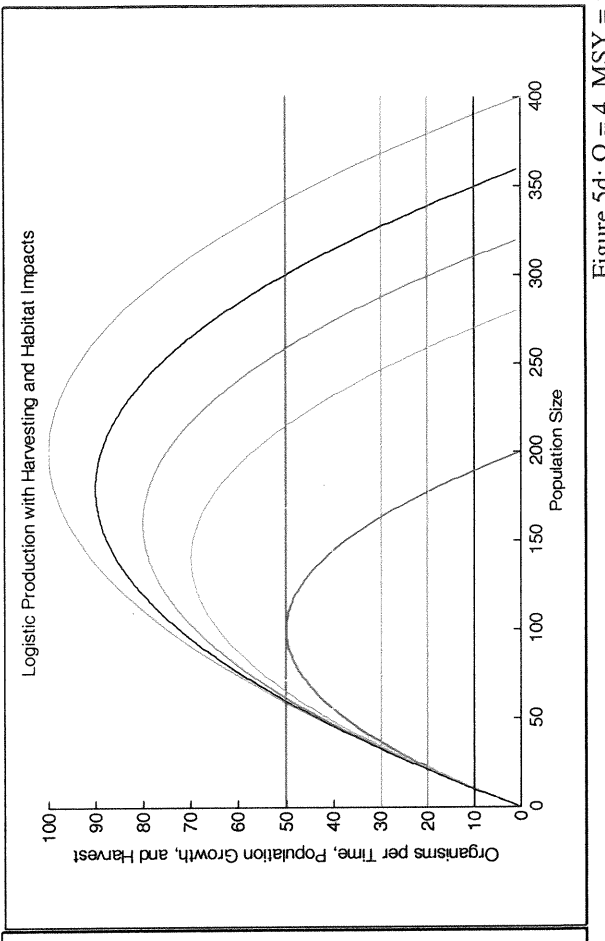


Figure 5d: $\Omega = 4$, MSY = 50.0

The previous analysis has examined the equilibrium conditions. It is also useful to examine the population trajectories for different constant harvest rates considering the fact that different constant harvest rates. Figure 6 shows an example of the impact of a positive value of Ω on the population trajectories corresponding to different constant harvest rates. At harvest rates above MSY the population crashes, and the higher the harvest rate is above MSY the sooner the crash occurs. At harvest rates equal to or less than MSY, the population stabilizes at the stock size where harvest rate equals the production of fish at equilibrium. MSY can be predicted from Equation (5), and at a harvest rate equal to MSY, the population equals the N_{max} from Equation (6).

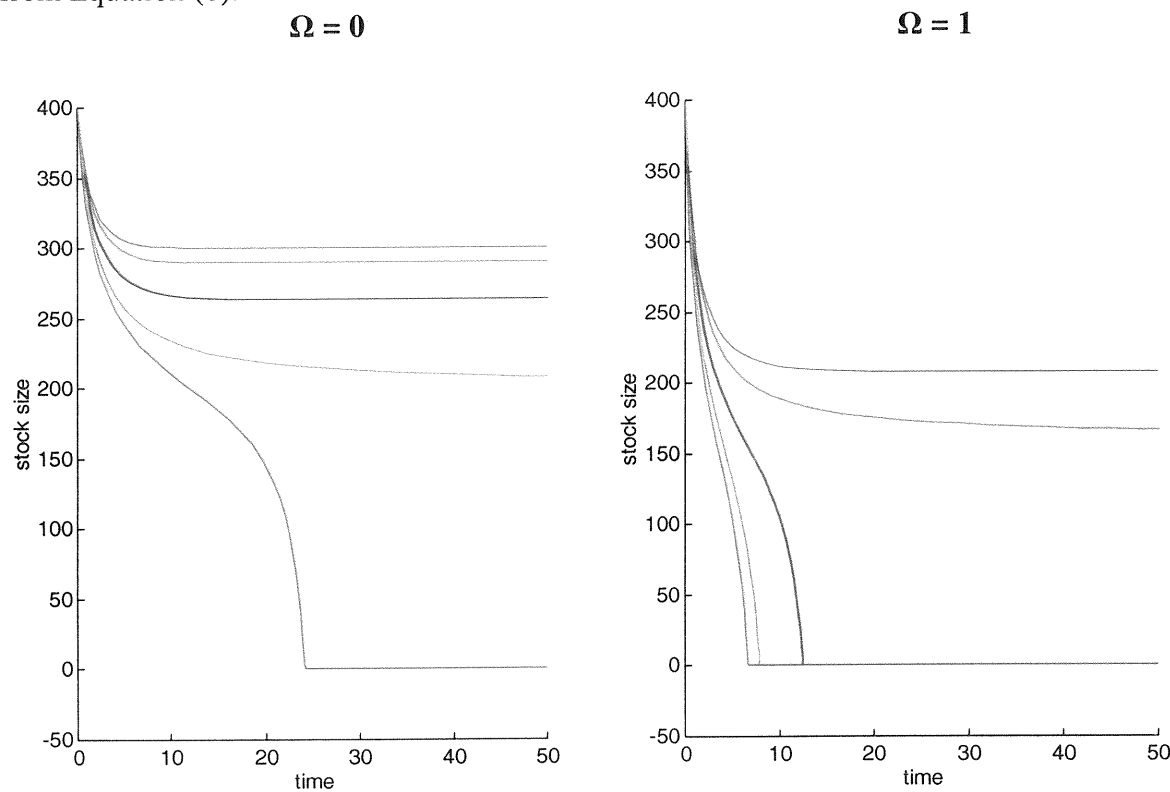


Figure 6: Population trajectories with different constant harvest rates without habitat impacts ($\Omega = 0$) and with habitat impacts ($\Omega = 1$). Both trajectories are for identical populations with $r = 1$ and $K = 400$ with an initial stock size of 400. Harvest rates correspond to colors: Magenta = 75; Green = 80; Blue = 90; Cyan = 100; Red = 105. Note that when $\Omega = 0$, the MSY is 100 (cyan) and occurs at a stock size of 200 at equilibrium. However, when $\Omega = 1$, the MSY is 80 (Green) and occurs at a stock size of 160. In both scenarios, harvest above MSY causes fish populations to collapse.

The Ω Value

Obviously, the success of this model relies on the ability to determine Ω . Since K is determined by the ecosystem in which fish and habitat are integral parts, the value Ω can be thought of as the extent to which fishing impacts the ecosystem. In general, this is determined by the level of damage caused by the gear type used, the vulnerability of the production function of the ecosystem, the extent to which the habitat produces fish, and the recovery rate. To represent this symbolically:

$$\Omega = f(g, \beta, v, r) \quad (7a)$$

where g is the degree of damage of the fishing methods to habitat features, i is the linkage between the habitat features and fish production, v is the vulnerability of the fish-producing features of the habitat to damaging fishing methods, and r is the recovery rate of the habitat features.

Finding the value of Ω can also be determined directly with data based on either of the following equalities:

$$K^* \% \Delta K = K - h^* \Omega \quad (7b)$$

$$\Omega = (K_0 - K_i) / h \quad (7c)$$

where K_0 is the initial carrying capacity before habitat impacts and K_i is the new carrying capacity as a result of the current rate of harvest (h), and $\% \Delta K$ is $(K_0 - K_i) / K_0$. Therefore, Ω can be determined if the initial carrying capacity, new carrying capacity, and harvest rate are known. Perhaps the most difficult information to acquire are the values for K_0 and K_i . However, as Equation 7a points out, these values must be functions of the distribution of habitat features, the sensitivity of those habitat features to the fishing gear type used to harvest fish, the recovery rate of those habitat features, and the production function linking carrying capacity of fish to those habitat features. The first three of these factors are incorporated in an existing model that determines a long-term effect index on each habitat feature.

This long-term effect index (LEI) can be determined using a methodology presented in Appendix B of the EFH DEIS that developed an impact rate for fishing based on the proportion of the habitat feature the fishing gear contacts per time and the proportion of the contacted features that are damaged or removed (see Appendix B, page B-5). The NMFS analysis also incorporated recovery in its effects of fishing model, but did not include the extent to which any of the habitat features contribute to the production of fish. The NMFS analysis incorporates the following four components:

1. Intensity of fishing effort
2. Sensitivity of habitat features to contact with fishing gear
3. Recovery rates of habitat features
4. Distribution of fishing effort relative to different types of habitat

These components are input into a model to derive an LEI value for each habitat, which are percent reductions in the original abundance of each habitat feature remaining at equilibrium as a result of current harvest rates and techniques (Appendix B). These LEI values for each habitat feature can be used to examine the reduction in contribution of each habitat feature to the carrying capacity of commercial fish populations.

Use of Habitat Suitability Index (HSI) models to determine production functions

The EFH DEIS repeatedly states that there is not enough information to determine a production function between habitat types. Without this type of information, a one-to-one production function between the quantity of habitat features and the production of fish should be assumed. Alternatively, NMFS should use the best available science (i.e. trawl survey data, observer data, submersible observations, etc) to develop production functions. Linking changes in LEI values to changes in carrying capacity requires identification of a production function that describes the relationship between inputs (habitat features) and outputs (carrying capacity).

Rubec (1999) described a methodology to determine this relationship based on Habitat Suitability Index models that identify relative species densities associated with each habitat feature. Since potential species density summed over all available habitats constitutes carrying capacity, the Habitat Suitability Index can be used to determine carrying capacity (Rubec et al. 1999).

The literature on Habitat Suitability Index (HSI) models makes it explicitly clear that the “value” of an area in terms of population productivity for a given species can be determined by relating animal abundance in space to the quality and availability of given habitats (Rubec et al. 1999; FWS 1980a, 1980b, 1981; Terrell et al. 1982; Bovee 1986; Bovee and Zuboy 1988). In these studies, habitat quality, synonymous with HSI, is determined based on the relative densities of fish species associated with each habitat type. The theory also assumes a linear relationship between habitat carrying capacity and HSI functions (Rubec et al. 1999; FWS 1981). Rubec et al. (1999) used CPUE as a surrogate measure for carrying capacity. The Rubec et al. (1999) study derived suitability index functions between fish and habitat using cumulative frequency method, range-mean method, smooth mean method depending on available data. The EFH EIS should consider which of these methods are most appropriate based on the data available. These values were plugged into a GIS database to develop habitat suitability maps for each species.

Rubec et al. (1999) suggested development of a production function model linking CPUE to amount of habitat features (i.e. $CPUE = f(X_1, X_2, \dots, X_n) + \text{error}$). Therefore, once the suitability of each habitat feature is developed for a fish species, a production function can be developed. Table 1 contains several potential equations for habitat-fishery linkage production functions for different ecological situations. The choice of model is based on the type of ecological relationship between the habitat feature and the carrying capacity. The values of variables and parameters can be determined by ecological studies such as species associations.

TABLE 1: Table of Potential Habitat-Fishery Production Functions

Habitat-Fishery Linkage Type	Example Model	Variables / Parameters:
One-to-one	$K = aX$	K = carrying capacity a, b = production coefficients X = Habitat feature X area α = Habitat X contribution to K Y = Habitat feature Y area β = Habitat Y contribution to K Z = Habitat feature Z area γ = Habitat Z contribution to K
Constant returns to scale	$K = aX^\alpha Y^\beta Z^\gamma \quad \{ \alpha + \beta + \gamma = 1 \}$	
Decreasing returns to scale	$K = aX^\alpha Y^\beta Z^\gamma \quad \{ \alpha + \beta + \gamma < 1 \}$	
Increasing returns to scale	$K = aX^\alpha Y^\beta Z^\gamma \quad \{ \alpha + \beta + \gamma > 1 \}$	
Facultative	$K = (a + bX^\alpha) Y^\beta Z^\gamma$	
Obligate	$K = aX + bX^\alpha Y^\beta Z^\gamma$	
Bottleneck	$K = (X/Y)^\alpha Y^\beta Z^\gamma$	
Substitute habitats	$K = aX^\alpha + bY^\beta$	

Incorporating the LEI values into this equation give the new carrying capacity K_i as a result of the habitat damage caused by fishing. For example, the generalizable formula incorporating LEI values for the constant returns to scale linkage type with three essential habitat features would be:

$$K_i = a(X(1-LEI_X))^\alpha (Y(1-LEI_Y))^\beta (Z(1-LEI_Z))^\gamma \quad (8)$$

For example, on February 15, 2004 at the American Association for the Advancement of Science Annual Meeting in Seattle, NMFS scientist Robert Stone reported values of 87% of all adult FMP fish and almost 100% of all juvenile FMP fish observed in a total of 23 km of 36 submersible dive sites at the Aleutian Islands to be associated with deep sea coral and sponge habitat, which are biogenic features of the seafloor producing refuge for commercial fish populations. Stone (pers. comm. 2004) used the following definitions:

Table 2: Types of fish-habitat associations considered by Stone (2004)

<i>Associated</i>	<i>Not Associated</i>
<ul style="list-style-type: none"> ▪ Resting in structured epifauna (i.e. physically in contact with it) ▪ Resting on seafloor adjacent to epifauna ▪ Slow swimming through epifauna ▪ Rapid swimming thru epifauna ▪ Hovering above epifauna (within 1 body length) ▪ Hovering within epifauna (within 1 body length, but not touching) 	<ul style="list-style-type: none"> ▪ Resting on biotically unstructured seafloor (not within 1 body length) ▪ Slow swimming over biotically unstructured seafloor ▪ Rapid swimming over unstructured seafloor ▪ Hovering in water column above unstructured seafloor

As was done in Rubec et al. (1999), this information can be used to develop Habitat Suitability Index values for each habitat type, and hence a production function. One example production function describing the case described by Stone's (2004) preliminary data is:

$$aX^{.87} * Y^{.13} = K \quad (8a)$$

where **X** is the quantity of deep sea coral and sponge habitat, **Y** is the quantity of biotically unstructured seafloor, and **K** is the carrying capacity of fish. Therefore, without habitat impacts, 100% of **X** and 100% of **Y** will yield 100% of the initial carrying capacity. However, considering the LEI values for hard corals as described in the LEI table above, there will be a 16% reduction in coral habitat in deep areas of the Aleutians. Assuming no change in other habitat features, the equation for percent change in carrying capacity is

$$(1-.16)^{.87} * (1)^{.13} = 0.86 \quad (8b)$$

Therefore, using this model, the current impacts of fishing reduce the carrying capacity and productivity of commercial fish to 86% of initial levels. If the carrying capacity of the current stock is known, a simple calculation can determine the initial carrying capacity, hence providing **K₀** and **K_i** values for determining **Ω** with Equation (7c). Therefore, the **Ω** value incorporates and extends the NOAA (2004b) Effects of Fishing model by incorporating habitat-fishery linkages to determine the adverse effects of fishing on the productivity of commercial fish species. Since carrying capacity is linearly proportional to MSY and N_{MSY} (from Equations (2) and (3)), this corresponds to a 14% reduction in productivity as a result of fishing. While this example from the best available science provided by Robert Stone was aggregated over all species, the model could easily be conducted on a species by species basis from the values presented in Table B.3-3 of Appendix B of the EFH DEIS.

Effects of this Model on the Methods and Conclusions of the EFH DEIS

This model presents a framework to use the mathematical model used in Appendix B to determine LEI values to simultaneously evaluate the effects of fishing on productivity and carrying capacity. It is clear from the results that if there are any negative effects of harvesting a fish population on the ecological functions that determine its carrying capacity, the true MSY for the fish stock is less than the value calculated from classic models of population dynamics such as the logistic growth equation. Note that the model only considers habitat features that contribute to the carrying capacity of the target species.

The benefit of the model presented here is that it allows agency scientists and analysts to determine the risks in productivity loss associated using different assumptions for the extent of habitat-fishery linkages in commercial fisheries given known levels of fishing impacts to habitat features. However, if the value of this parameter continues to be assumed to be zero, this model indicates a high risk of future overfishing for populations that are harvested at the MSY determined by conventional models (see Figure 6), particularly if equilibrium LEI values have not yet been reached. Also, because a positive value of Ω lowers the production at all stock sizes along the production function, values of MSST calculated for a fishery with habitat impacts will be lower than the MSST without fishing impacts. This demonstrates a significant argument against the methodology of comparing stock sizes to MSST as a method to measure habitat impacts, which is the fundamental methodology used in the Alaska Region EFH DEIS.

The abundance of prey species for commercial fish may also be a major determinant of a fish population's carrying capacity; therefore, if harvesting a target species also reduces the abundance of that species' prey, carrying capacity may also be reduced. The most obvious way a fishery may do this is through the incidental catch, or 'bycatch', of prey species. Bycatch occurs at different rates for each fishery and gear type, but is known to be a major problem in some fisheries, particularly those prosecuted with bottom trawls. Bycatch levels may be significant. For example, approximately 366,015,500 pounds of groundfish were discarded annually as bycatch from 1997 to 2002 (FIS 2003). While the precise effect of this bycatch on the carrying capacity of commercial species is not currently known, this illustrates the potential for values of Ω above zero as a result of bycatch. It is unclear why bycatch and discards in Alaska's groundfish fisheries were not incorporated or considered by NMFS in the analysis of reduced prey on the habitat quality of FMP species.

Fishermen and fishery managers may strongly influence the value of Ω for their fisheries. Perhaps the most obvious way to do this is through the gear type they use to catch fish. Many fisheries can be harvested with multiple gear types. For example, the Pacific Cod Fishery in Alaska is prosecuted with bottom trawls, bottom longlines, and traps, each of which clearly has a different level of impact on habitat features and different rates of bycatch per fish caught. Therefore, by converting fishing gears from bottom trawls to longlines, fishermen can reduce the value of Ω for their fisheries. This shows that Ω will vary between different mitigation alternatives selected.

In addition, the locations where fish are harvested will affect the degree to which fishing effort damages fish habitat. For example, Shester and Ayers (in press) found that the catch per unit effort of corals and sponges varies greatly by area in the Aleutian Islands and that it is possible to identify specific fishing locations in this region with high catch rates of target species and relatively low bycatch rates of corals and sponges. Therefore, fisheries measures that change fishing effort distributions by prohibiting bottom trawling in areas with high bycatch rates, while

concentrating fishing effort into areas that are less vulnerable to fishing impacts will reduce the value of Ω .

As fishermen will quickly note, changes to fishing methods such as area restrictions and gear type conversions can increase their cost of fishing. These additional costs have been the major deterrent for conservation organizations seeking to impose these changes through regulations. However, these costs must be weighed against the benefits. The model presented here provides a methodology to quantify the economic benefits to fishermen from these measures. For any change in the value of Ω , the model shows the resulting change in the maximum sustainable yield of the fish population (see Figure 4). The value of this change can easily be determined by economic measures such as the ex-vessel or market price of the fish as was done in the EFH DEIS to determine changes in revenue. Therefore, this model makes it possible to conduct cost-benefit analyses of measures that mitigate the effects of fishing on habitat that may be used in determining the practicability of such measures. However, there may be additional benefits of reducing habitat impacts on features of the marine ecosystem other than increases in target species productivity. The model presented here is explicitly limited to effects of fishing on the target species only, so it must not be used as the sole measure of the benefits of reductions in the habitat impacts of fishing. There also may be other benefits to target species of effort reductions and trawl closures, such as increased resilience to environmental changes, increased stability in TACs, greater target species CPUEs, and reduced fishing costs (Mangel 2000; Rodwell et al. 2002)

As in any mathematical model, there are some caveats to the productivity impacts model presented in these comments. Like the LEI model used in the EFH DEIS, it is a static model showing the effects of fishing on habitat at equilibrium. Therefore, changes in harvest rate, environmental stochasticity, and other changes in environmental conditions over time are not incorporated in the model. In addition, the production functions of fisheries do not always take the shape of a symmetric parabola, but are sometimes skewed to one side or another. The concept of the model can easily be incorporated into different logistic growth equations, but these are not presented here. Rather, the model represents a specific conceptual framework for considering the effects of fishing on the carrying capacity of the target species and should be viewed as such. The model also does not consider fishing impacts to other features of the marine ecosystem, such as biodiversity, ecosystem health, or the productivity of non-target species. These considerations are important in habitat conservation methods, but are outside the scope of this paper. It is also important to note that the model presented here only considers the impact of fishing on carrying capacity. Since carrying capacity is generally related to resource availability, the model is limited to these types of effects. While habitat quality and quantity certainly affects carrying capacity, there may be other ways that habitat impacts affect population growth.

One potential way to improve this model would be to address the impacts of harvest on the intrinsic rate of increase (r) in the logistic growth equation. This type of effect may be warranted when habitat impacts affect recruitment rather than resource availability or habitat suitability. Changes in r will have different effects on the production function and the MSY than changes in K , as discussed earlier. A more comprehensive model of habitat-mediated impacts of fishing on target species productivity should include how harvest level affects both r and K . Other models, such as Beverton-Holt and Ricker use similar logistic equations with spawner-recruitment functions. While I do not claim to be an expert on the specific fishery models used in the North Pacific, it is clear that NMFS has the resources to develop models such as the one I have described that are based on the specific models used to determine Optimum Yield and

TACs for North Pacific groundfish. If NMFS is using productivity to determine whether habitat impacts are minimal, NMFS should call on its expertise to develop such a model for the species harvested under the BSAI and GOA Groundfish FMPs, rather than current stock size in relation to MSST.

A potential extension of this model would be to extend the impacts of harvest of other fisheries on the target fish population. For example, fishing for one species may affect the habitat, and thus the carrying capacity of another. This would be analogous to the well-known Lotka-Volterra competition equations where the presence of competing species reduces the production of each individual species. However, in this case, the harvest of one species, for example, the Alaska flatfish trawl fishery, could impact the carrying capacity of red king crab by damaging its habitat. Therefore, the framework for understanding the carrying capacity effects of fishing has the potential to provide a very useful tool in ecosystem-based management.

Viewing habitat impacts through this conceptual framework highlights the need for directed research on the production function between habitat features and commercial fish species. It is likely that multiple habitat features contribute to the intrinsic rate of increase (r) and the carrying capacity (K) of each fish population. Understanding and quantifying the linkages between these habitat features and the values of r and K will provide the research necessary to determine more precise values of Ω for input into this model.

This model provides a quantitative methodology to describe what marine conservation advocates have been claiming for years: that destructive fishing decreases the productivity of commercial fisheries. It also provides a conceptual framework for comparing the costs and benefits of changes in fishing methodologies with respect to their impacts on commercial fish habitat. Though this model has its caveats, it can and should be incorporated into the current policy discussions regarding the evaluation of adverse impacts of fishing on fish habitat and potential measures to reduce or mitigate those impacts.

Selection of a Preferred EFH Mitigation Alternative

Due to the omissions and methodological problems with the EFH DEIS determination of adverse impacts to EFH as well as the overwhelming evidence from observer bycatch records, LEI values from the EFH DEIS, and the scientific literature on the effects of bottom trawling, it is clear that the adverse effects of fishing on EFH are more than minimal and more than temporary, particularly for corals, sponges, and other structural biogenic habitats in the Aleutian Islands. Therefore, selection of the status quo EFH mitigation alternative (Alternative 1) would violate the Magnuson-Stevens Fishery Management and Conservation Act (16 U.S.C. 1863(a)(7)).

I have attached a copy of the manuscript submitted by Jim Ayers and myself to the 2nd International Symposium on Deep Sea Corals in Erlangen, Germany in September 2003. This manuscript, entitled “A Cost Effective Approach to Protecting Deep Sea Coral and Sponge Ecosystems with an Application to Alaska’s Aleutian Islands Region” describes the approach and development of Alternative 5B and has been peer-reviewed and accepted for publication in the Symposium Proceedings.

Alternative 5B is the most practicable and cost-effective alternative for minimizing the adverse impacts of fishing on EFH in the Aleutian Islands. This alternative was the only alternative crafted specifically to maximize conservation benefits to EFH while minimizing

reductions in catch necessary to ensure that effort does not increase in remaining open areas. For example, no other alternative in the Aleutian Islands comes close to a ratio of the 78% of the fishable habitat protected from bottom trawling with only a 6-12% reduction in catch; and contrary to statements made in the EFH DEIS about Alternative 5B shifting effort into Steller sea lion habitat, Alternative 5B is the only alternative that specifically reduces trawl effort to avoid such problems.

However, the reduction in Pacific cod TAC in the Bering Sea under this alternative is not justified based on the need to reduce effort by the amount that historically occurred in areas that will become closed, as is discussed in NRC (2002). Therefore, the TAC should be split between the AI and BS as is done for other species and TAC should be reduced in the Aleutian Islands region only. This is further justified by the Kanno et al. (2001) finding that there are distinct subpopulations of Pacific cod in the North Pacific.

Therefore, for the sake of future fishermen, future Alaskans, and the humbling magnificence of Alaska's marine environment, I wholeheartedly ask you to adopt Alternative 5B as the Preferred Alternative for minimizing the adverse impacts of bottom trawling on EFH.

Coral and sponge habitat destroyed in top 75% species concentration (from Table B.3-3):

Golden King Crab:	14% of hard coral in AI shallow, 25% of hard coral in AI deep
Pacific Cod:	19% of hard coral in AI shallow, 24% of hard coral in AI deep
Sablefish:	12% of hard coral in AI shallow, 54% of hard coral in AI deep
Atka mackerel :	40% of hard coral in AI shallow, 40% of hard coral in AI deep
POP:	21% of hard coral in AI shallow, 38% of hard coral in AI deep
Shortraker/rougheye:	13% of hard coral in AI shallow, 27% of hard coral in AI deep
Northern rockfish:	28% of hard coral in AI shallow, 34% of hard coral in AI deep
Dusky rockfish:	63% of hard coral in AI shallow, 55% of hard coral in AI deep
Yelloweye rockfish:	36% of hard coral in AI shallow, 46% of hard coral in AI deep
Thornyheads:	9% of hard coral in AI shallow, 27% of hard coral in AI deep
Walleye pollock:	8% of hard coral in AI shallow, 16% of hard coral in AI deep

Thank you for considering these comments.

Sincerely,

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Attachment: Shester and Ayers manuscript submitted to 2nd International Symposium on Deep Sea Corals

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